Rhenium Catalyzed 1,3-Isomerization of Allylic Alcohols: Scope and Chirality Transfer

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General Information

The ^{1}H and ^{13}C NMR spectra were recorded at 300 MHz and 75 MHz, respectively. Chemical shifts are reported in parts per million (ppm) downfield from tetramethylsilane (TMS) with reference to the internal solvent. Multiplicities are abbreviated as follows: singlet (s), doublet (d), triplet (t), quartet (q), quintet (quint), multiplet (m), and broad (br). The reported ^{1}H NMR and ^{13}C NMR data refer to the major alkene isomer (which is identified) except when otherwise noted. Assignment of the *E*/*Z* stereochemistry for the disubstituted alkenes was based upon the coupling constants of their vinylic protons, and that for the trisubstituted alkenes was based upon NOE experiments. 2D NOESY experiments were obtained using a 5 mm dual $^{1}H/^{13}C$ Z-gradient probe at 23 ^{o}C using a **noesytp** pulse program was used with the following acquisition parameters. F2 and F1 sweep widths, 2913 Hz. F2 and F1 digital resolution, 2.8 Hz/pt. 256 FIDs recorded, each consisting of 8 scans and 1024 data points (AQ = 0.176 s). A mixing time of 800 ms was set as a simple delay. A recycle delay of (D1) of 2.0 s was employed. Processing parameters: $\pi/2$ shifted sine^{2} (QSINE, SSB=2) apodization was applied in both dimensions prior to the Fourier transformation. High-resolution mass spectra (EI, CI, or FAB) were obtained using EI, CI and FAB techniques. Flash column chromatography employed silica gel 60 (230-400 mesh). Ether, CH_2Cl_2, benzene, and THF were purified and dried by passage through a solvent column.[1] All other chemicals were used as purchased, unless otherwise noted. Experimental procedures and characterization data for compounds **14**, **15**, **18a**, **19a**, **22a**, **23a**, **24-31**, **36b**, **37b**, **42a-c** and **44a** were given in a previous communication.[2]

Specific Experimental Procedures and Characterization Data

Triphenylsilyl perrhenate (**1**).[3] In glove box, added Re_2O_7 (1.64 g, 3.4 mmol) and triphenylsilanol (2.06 g, 7.5 mmol) to a 100-mL round-bottomed flask. Added dry toluene (24 mL) and let stir at room temperature for 1 hour. Filtered through Celite in the glove box and removed solvent *in vacuo*. Dissolved the residue in a small amount of dry ether and placed in the drybox freezer (- 40 ^oC) overnight. After vacuum filtration, 1.81 g (52% yield) of **1** was obtained as white crystals. A second crop of 720 mg of **1** (73% yield, total) from the mother liquor. ^1H NMR indicated that the product contained a small (< 5%) amount of triphenylsilanol. This impurity was never completely removed. Isolated **1** could be stored over long periods of time (many months) at -40 ^oC in the glove box. ^1H NMR (300 MHz, C_6D_6, ppm): δ 7.61 (triphenylsilanol, 6H, m), 7.38 (6H, m), 7.06 (9H, m), 7.06 (triphenylsilanol, 9H, m). HRMS (EI) calcd. for $C_{18}H_{15}O_4ReSi$: 510.0297, found: 510.0296.

(*Z*)-1-(4-nitrophenyl)non-2-en-1-ol (**18b**). *Step 1*: Followed procedure given for **20** (Step 1), with 27 mL (183 mmol) 1-octyne, 100 mL (160 mmol) *n*-butyllithium (1.6M in hexanes), 18.6 g (123 mmol) 4-nitrobenzaldehyde, and 300 mL THF. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 29 g of 1-(4-nitrophenyl)non-2-yn-1-ol as a red oil (90% yield). Dissolved in hexanes and kept under vacuum (ca. 0.03 torr) overnight to isolate this product as an orange solid. ^1H NMR (300 MHz, $CDCl_3$, ppm): δ 8.23 (2H, d, J = 8.7 Hz), 7.72 (2H, dd, J = 8.9, 0.5 Hz), 5.55 (1H, d, J = 5.1 Hz), 2.36 (1H, d, J = 5.7 Hz), 2.27 (2H, td, J = 7.1, 2.1 Hz), 1.5 (2H, m), 1.31 (6H, m), 0.89 (3H, t, J = 6.9

Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 148.3, 147.8, 127.5, 123.9, 89.2, 79.1, 64.0, 31.4, 28.7, 28.6, 22.7, 19.0, 14.2. HRMS (EI) calcd. for $C_{15}H_{19}NO_3$: 261.1365, found: 261.1350. *Step 2*: To a 50 mL round-bottomed flask, added 1-(4-nitrophenyl)non-2-yn-1-ol (784 mg, 3.0 mmol), Lindlar catalyst (5% Pd on $CaCO_3$, poisoned with Pb, 30 mg), and EtOAc (30 mL). Evacuated flask (aspirator vacuum) and placed under a H_2 atmosphere, stirring at 1000 rpm at room temperature. Kept under static H_2 atmosphere and stopped reaction by evacuating flask after a little over 1 equivalent of H_2 had been consumed (monitored by displacement of water in an attached biuret, approximately 1 hour).[4] Filtered through Celite, rinsing with EtOAc, and purified via silica gel chromatography (8:2 pentane:ether) to obtain 789 mg of **18b** as an orange oil (99% yield, *Z*:*E* > 20:1 by ^{1}H NMR). ^{1}H NMR (300 MHz, C_6D_6, ppm): δ 7.88 (2H, dt, *J* = 9.0, 2.2 Hz), 7.09 (2H, dtd, *J* = 9.0, 2.2, 0.9 Hz), 5.31 (2H, m), 5.16 (1H, dd, *J* = 7.7, 2.3 Hz), 1.9 (2H, m), 1.25 (1H, br), 1.25 (8H, m), 0.90 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, C_6D_6, ppm): δ 151.0, 147.4, 132.9, 131.6, 126.6, 123.6, 68.7, 32.0, 29.8, 29.2, 27.9, 23.0, 14.3. HRMS (EI) calcd. for $C_{15}H_{21}NO_3$: 263.1521, found: 263.1522.

(*E*)-1-(4-nitrophenyl)non-1-en-3-ol (**19b**). Followed procedure given for **21**, with 105.2 mg (0.4 mmol) **18b**, 4 mg (0.008 mmol) **1**, 2 mL ether, a reaction temperature of 0 °C, and a reaction time of 30 min. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 98.5 mg of **19b** as a yellow oil (94% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 8.16 (2H, dt, *J* = 9.0, 2.3 Hz), 7.49 (2H, dt, *J* = 9.0, 2.3 Hz), 6.66 (1H, d, *J* = 15.9 Hz), 6.42 (1H, dd, *J* = 16.1, 6.2 Hz), 4.34 (1H, dtd, *J* = 6.3, 6.3, 1.0 Hz), 1.90 (1H, br), 1.46 (10H, m), 0.88 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 147.0, 143.6,

137.8, 127.8, 127.1, 124.2, 72.7, 37.5, 31.9, 29.4, 25.5, 22.8, 14.2. HRMS (EI) calcd. for $C_{15}H_{21}NO_3$: 263.1521, found: 263.1517.

(*E*)-1-(4-(trifluoromethyl)phenyl)non-2-en-1-ol (**20**). *Step 1*: To a flame-dried, round-bottomed flask, under an argon atmosphere, added 1-octyne (6.5 mL, 44 mmol) and ether (120 mL). Placed in a dry ice/acetone bath and let stir for approximately 10 minutes. Added a 1.6 M hexanes solution of *n*-butyllithium (24 mL, 38 mmol) dropwise and let stir at –78 °C for 30 minutes. Added, at –78 °C, a solution of α,α,α-trifluoro-*p*-tolualdehyde (4 mL, 30 mmol) and ether (30 mL) dropwise. Let stir at –78 °C for 1 hour, then removed dry ice/acetone bath and let slowly warm to room temperature. Quenched by slow addition of 100 mL aqueous NH_4Cl solution, extraction 3 times with 100 mL ether, and drying with Na_2SO_4. Purified via silica gel chromatography (7:3 pentane:ether) to obtain 8.7 g of 1-(4-(trifluoromethyl)-phenyl)non-2-yn-1-ol as a pale yellow oil (99% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.65 (4H, m), 5.51 (1H, d, *J* = 6.0 Hz), 2.28 (2H, td, *J* = 7.1, 1.9 Hz), 2.28 (1H, br), 1.4 (8H, m), 0.90 (3H, t, *J* = 6.9 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 145.2, 133.9 (q, *J* = 129 Hz), 127.1, 125.7, (q, *J* = 15.0 Hz), 124.3 (q, *J* = 1082 Hz), 88.7, 79.5, 64.4, 31.5, 28.8, 28.7, 22.7, 19.0, 14.2. HRMS (EI) calcd. for $C_{16}H_{19}F_3O$: 284.1388, found: 284.1390. *Step 2:* To a flame-dried, round-bottomed flask, under an argon atmosphere, added 1-(4-(trifluoromethyl)-phenyl)non-2-yn-1-ol (3 mL, 11.6 mmol), 85% manganese(IV) oxide (12 g, 117 mmol), and benzene (150 mL). Let stir at room temperature for 16.5 hours, then filtered through Celite, rinsing with ether. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 3.13 g of 1-(4-(trifluoromethyl)phenyl)non-2-yn-1-one as an orange oil (96% yield). ^{1}H NMR (300 MHz,

$CDCl_3$, ppm): δ 8.25 (2H, d, *J* = 8.1 Hz), 7.75 (2H, d, *J* = 8.1 Hz), 2.53 (2H, t, *J* = 7.2 Hz), 1.70 (2H, m), 1.40 (6H, m), 0.92 (3H, t, *J* = 7.1 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 177.1, 139.7, 135.2 (q, *J* = 130 Hz), 130.0, 125.8 (q, *J* = 15.0 Hz), 123.8 (q, *J* = 1085 Hz), 98.7, 80.0, 31.4, 28.9, 27.9, 22.7, 19.5, 14.2. HRMS (EI) calcd. for $C_{16}H_{17}F_3O$: 282.1231, found: 282.1223. *Step 3*: To a flame-dried, round-bottomed flask, under an argon atmosphere, added 1-(4-(trifluoromethyl)-phenyl)non-2-yn-1-one (1.88 g, 6.66 mmol) and THF (50 mL). Placed in an ice bath and added a 1.0 M THF solution of lithium aluminum hydride (20 mL, 20 mmol) dropwise. Immediately removed ice bath and let stir at room temperature After 84 hours the solution was cooled to 0 ^{o}C, then 30 mL EtOAc and a few scoops of Na_2SO_4•$10H_2O$ was added. Removed ice bath and let stir at room temperature for approximately 20 minutes. Filtered the resulting suspension through Celite, rinsing with diethyl ether. Purified via silica gel chromatography (7:3 pentane:ether) to obtain 1.4 g of **20** as a yellow oil (73% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.61 (2H, d, *J* = 8.4 Hz), 7.50 (2H, d, *J* = 8.1 Hz), 5.81 (1H, dt, *J* = 15.3, 6.7 Hz), 5.62 (1H, ddt, *J* = 15.3, 6.9, 1.4 Hz), 5.23 (1H, dd, *J* = 6.9, 3.0 Hz), 2.07 (2H, dt, *J* = 6.9 Hz), 1.95 (1H, d, *J* = 3.3 Hz), 1.3 (8H, m), 0.89 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 147.4 (d, *J* = 4.5 Hz), 134.2, 131.9, 129.8 (q, *J* = 129 Hz), 126.6, 125.5 (q, *J* = 15.0 Hz), 124.4, (q, *J* = 1081 Hz), 74.9, 32.4, 31.8, 29.1, 29.0, 22.8, 14.2. HRMS (EI) calcd. for $C_{16}H_{21}F_3O$: 286.1544, found: 286.1552.

(*E*)-1-(4-(trifluoromethyl)phenyl)non-1-en-3-ol (**21**). In glove box, added **1** (6 mg, 0.012 mmol) to 4-mL vial. Removed from glove box, added ether (2 mL), placed in Cryotrol set to –50 °C, and let stir for approximately 10 minutes. Added **20** (114.6 mg, 0.4 mmol) via

syringe and let stir at –50 °C for 1 hour. Removed from Cryotrol, immediately added 20 μL triethylamine, and let stir until warmed to room temperature. Concentrated *in vacuo* and purified directly via silica gel chromatography (8:2 pentane:ether) to obtain 112.9 mg of **21** as an oil (98% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.57 (2H, d, *J* = 8.4 Hz), 7.47 (2H, d, *J* = 8.4 Hz), 6.62 (1H, d, *J* = 15.9 Hz), 6.33 (1H, dd, *J* = 15.9, 6.0 Hz), 4.32 (1H, dt, *J* = 6.2, 6.2 Hz), 1.79 (1H, br), 1.65 (2H, m), 1.35 (8H, m), 0.90 (3H, t, *J* = 7.1 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 140.5 (d, *J* = 5.4 Hz), 135.5, 129.6 (q, *J* = 129 Hz), 128.8, 126.8, 125.7 (q, *J* = 15.4 Hz), 124.4, (q, *J* = 1081 Hz), 72.9, 37.6, 32.0, 29.4, 25.6, 22.8, 14.3. HRMS (EI) calcd. for $C_{16}H_{21}F_3O$: 286.1544, found: 286.1537.

(*E*)-1-(4-methoxyphenyl)non-2-en-1-ol (**22b**). Followed procedure given for **20**, with: *Step 1*: 10 mL (67.7 mmol) 1-octyne, 31 mL (49.6 mmol) *n*-butyllithium (1.6M in hexanes), 5 mL (41.2 mmol) *p*-anisaldehyde, and 60 mL ether. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 9.96 g of 1-(4-methoxyphenyl)non-2-yn-1-ol[5] as a light yellow oil (98% yield). *Step 2*: 3 mL (13 mmol) 1-(4-methoxyphenyl)non-2-yn-1-ol, 39 mL (39 mmol) lithium aluminum hydride (1.0M in THF), 100 mL THF, and a reaction time of 68 hours. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 2.35 g of **22b** as an oil (73% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.30 (2H, d, *J* = 8.7 Hz), 6.89 (2H, d, *J* = 8.7 Hz), 5.71 (2H, m), 5.13 (1H, dd, *J* = 5.9, 3.2 Hz), 3.81 (3H, s), 2.06 (2H, dt, *J* = 6.7, 6.7 Hz), 1.86 (1H, br), 1.34 (8H, m), 0.89 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 159.2, 135.9, 132.7, 132.5, 127.7, 114.0, 75.0, 55.5, 32.4, 31.9, 29.3, 29.1, 22.8, 14.3. HRMS (EI) calcd. for $C_{16}H_{24}O_2$: 248.1776, found: 248.1787.

(*E*)-1-(4-methoxyphenyl)non-1-en-3-ol (**23b**). Followed procedure given for **21**, with 99.1 mg (0.4 mmol) **22b**, 4 mg (0.016 mmol) **1**, 2 mL ether, a reaction temperature of –78 °C, and a reaction time of 120 minutes. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 78.7 mg of **23b** as an oil (79% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.32 (2H, d, *J* = 8.4 Hz), 6.86 (2H, d, *J* = 9.0 Hz), 6.51 (1H, d, *J* = 15.9 Hz), 6.09 (1H, dd, *J* = 16.1, 7.1 Hz), 4.25 (1H, dt, *J* = 6.6, 6.6 Hz), 3.81 (3H, s), 1.74 (1H, br), 1.5 (10H, m), 0.90 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 159.4, 130.7, 130.0, 129.7, 127.8, 114.2, 73.5, 55.5, 37.6, 32.0, 29.4, 25.6, 22.8, 14.3. HRMS (EI) calcd. for $C_{16}H_{24}O_2$: 248.1776, found: 248.1768.

1-(Benzofuran-2-yl)prop-2-en-1-ol (**34a**). To a flame-dried, round-bottomed flask, under an argon atmosphere, added benzofuran-2-carbaldehyde (1.24 mL, 10.2 mmol) and ether (20 mL). Placed in an ice bath and added a 1.0M THF solution of vinylmagnesium bromide (20.4 mL, 20.4 mmol) dropwise. Removed ice bath shortly thereafter and let stir at room temperature for 2 hours. Slowly added 50 mL aqueous NH_4Cl solution, extracted 3 times with 20 mL ether, and dried with Na_2SO_4. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 1.52 g of **34a** as a clear oil (86% yield). bp 140 ^{o}C (ABT) / 0.1 mmHg. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.55 (2H, m), 7.48 (2H, m), 7.25 (2H, m), 6.63 (1H, s), 6.19 (1H, m), 5.50 (1H, d, *J* = 17.0 Hz), 5.35 (1H, m), 5.34 (1H, d, *J* = 10.5 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 157.5, 154.9, 136.3, 127.9, 124.3, 122.8, 121.1, 117.2, 111.3, 103.3, 69.1. HRMS (EI) calcd. for $C_{11}H_{10}O_2$: 174.0681, found: 174.0675.

(*E*)-1-(benzofuran-2-yl)non-2-en-1-ol (**34b**). Followed procedure given for **20**, with: *Step 1*: 1.56 mL (12.3 mmol) 1-octyne, 7.8 mL (12.3 mmol) *n*-butyllithium (1.6M in hexanes), 1.24 mL (10.2 mmol) benzofuran-2-carbaldehyde, and 15 mL ether. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 2.06 g of 1-(benzofuran-2-yl)non-2-yn-1-ol as a yellow oil (79% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.55 (2H, m), 7.46 (1H, m), 7.24 (2H, m), 6.79 (1H, s), 5.58 (1H, dd, *J* = 6.6, 1.9 Hz), 2.56 (1H, Ψt, *J* = 5.5 Hz), 2.28 (2H, dt, *J* = 1.9, 7.2 Hz), 1.5 (2H, pent, *J* = 7.2 Hz), 1.43 – 1.26 (8H, m), 0.84 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75 MHz, $CDCl_3$, ppm): δ 1.55.9, 155.2, 127.8, 124.5, 122.8, 121.3, 111.4, 103.9, 87.7, 66.8, 58.8, 31.3, 28.5, 28.3, 22.5, 18.7, 13.9 HRMS (EI) calcd. for $C_{17}H_{20}O_2$: 256.1463, found: 256.1459. *Step 2*: 2.61 g (10.2 mmol) 1-(benzofuran-2-yl)non-2-yn-1-ol, 30.6 mL (30.6 mmol) lithium aluminum hydride (1.0M in THF), 30 mL THF and a reaction time of 24 hours. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 1.5 g of **34b** as a clear oil (58% yield). bp 200 ^{o}C (ABT) / 0.2 mmHg. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.54 (2H, m), 7.47 (2H, m), 7.24 (2H, m), 6.62 (1H, s), 5.85 (2H, m), 5.30 (1H, Ψt, *J* = 6.8 Hz), 2.23 (1H, d, *J* = 4.7 Hz), 2.11 (2H, q, *J* = 6.8 Hz), 1.44 – 1.28 (8H, m), 0.89 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75 MHz, $CDCl_3$, ppm): δ 158.29, 154.90, 150.80, 135.09, 128.15, 128.08, 124.13, 122.72, 121.03, 111.23, 102.87, 69.15, 32.19, 31.64, 28.82, 22.57, 14.06. HRMS (EI) calcd. for $C_{17}H_{22}O_2$: 258.1620, found: 258.1617.

(*E*)-3-(benzofuran-2-yl)prop-2-en-1-ol (**35a**). Followed procedure given for **21**, with 87 mg (0.5 mmol) **34a**, 5 mg (0.01 mmol) **1**, 2 mL THF, a reaction temperature of –50 ^{o}C and

a reaction time of 30 min. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 86 mg of **35a** as white, crystalline solid (98% yield). mp 61-63 ^{o}C. ^{1}H NMR (300 MHz, C_6D_6, ppm): δ 7.34 (2H, m), 7.05 (2H, m), 6.45 (1H, dt, *J* = 15.9, 4.4 Hz), 6.35 (1H, dt, *J* = 15.7, 1.1 Hz), 6.22 (1H, s), 3.83 (2H, m), 0.9 (1H, s). ^{13}C NMR (75.4 MHz, C_6D_6, ppm): δ 155.7, 155.4, 132.1, 129.8, 125.2, 123.5, 121.6, 118.6, 111.6, 104.9, 62.9. HRMS (EI) calcd. for $C_{11}H_{10}O_2$: 174.0681, found: 174.0677.

(*E*)-1-(benzofuran-2-yl)non-1-en-3-ol (**35b**). Followed procedure given for **21**, with 103 mg (0.4 mmol) **34b**, 4 mg (0.008 mmol) **1**, 2 mL THF, a reaction temperature of –50 ^{o}C, and a reaction time of 30 min. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 101 mg of **35b** as a clear oil (98% yield). ^{1}H NMR (75.4 MHz, C_6D_6, ppm): δ 7.36 (2H, m), 7.06 (2H, m), 6.53 (1H, dd, *J* = 5.3, 15.7 Hz), 6.40 (1H, dd, *J* = 0.8, 15.8 Hz), 6.27 (1H, s), 4.01 (1H, m), 1.4-1.2 (10 H, m), 1.06 (1H, bs), 0.88 (3H, t, *J* = 6.6 Hz) ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 155.72, 155.46, 136.19, 129.87, 125.20, 123.53, 121.51, 118.25, 111.56, 72.36, 38.10, 32.52, 30.01, 26.03, 23.37, 14.68. HRMS (EI) calcd. for $C_{17}H_{22}O_2$: 258.16198, found: 258.16318.

1-(Thiophen-2-yl)prop-2-en-1-ol (**36a**). Following the procedure given **34a**, with 5 mL 2-thiophene-carboxaldehyde (54.5 mmol), 100 mL 1.0M THF solution of vinylmagnesium bromide (100 mmol) and 100 mL ether. Purified via silica gel chromatography (7:3 pentane:ether) to obtain ca. 7 g of **36a** as a yellow oil (92% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.55 (1H, m), 7.27 (2H, m), 6.41 (1H, ddd, *J* = 17.2, 10.3, 5.9 Hz), 5.7 (2H, m), 5.53 (1H, dt, *J* = 10.5, 1.2 Hz), 2.47 (1H, br). ^{13}C NMR (75.4 MHz, $CDCl_3$,

ppm): δ 146.8, 139.5, 127.0, 125.5, 124.6, 116.0, 71.2. HRMS (EI) calcd. for C_7H_8OS: 140.0296, found: 140.0291.

(*E*)-3-(thiophen-2-yl)prop-2-en-1-ol (**37a**). Followed procedure given for **21**, with 112.2 mg (0.8 mmol) **36a**, 8 mg (0.016 mmol) **1**, 4 mL THF, a reaction temperature of –50 °C, and a reaction time of 30 min. Purified via silica gel chromatography (7:3 pentane:ether) to obtain 78.2 mg of **37a** as an oil (70% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.16 (1H, m), 6.96 (2H, m), 6.74 (1H, d, *J* = 15.6 Hz), 6.20 (1H, dt, *J* = 15.6, 5.8 Hz), 4.26 (*E*-isomer, 1.93H, dd, *J* = 5.7, 1.2 Hz), 3.64 (*Z*-isomer, 0.067H, d, *J* = 6.9 Hz), 2.16 (1H, br). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 141.9, 128.3, 127.5, 126.0, 124.5, 124.4, 63.4. HRMS (EI) calcd. for C_7H_8OS: 140.0296, found: 140.0288.

1-(1-Tosyl-1*H*-indol-3-yl)prop-2-en-1-ol (**38a**). Followed procedure given for **34a**, with 8 g (27 mmol) 1-tosyl-1*H*-indole-3-carbaldehyde,[7] 100 mL (100 mmol) vinylmagnesium bromide (1.0M in THF), and 50 mL THF. Purified via silica gel chromatography (1:1 pentane:ether). Subsequent recrystallization from MeOH yielded 4.5 g of **38a** as a fine white powder (51% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.98 (1H, d, *J* = 8.1 Hz), 7.78 (2H, d, *J* = 8.1 Hz), 7.65 (1H, d, *J* = 7.8 Hz), 7.54 (1H, s), 7.33 (1H, t, *J* = 7.2 Hz), 7.24 (3H, m), 6.17 (1H, m), 5.45 (1H, m), 5.45 (1H, d, *J* = 16.8 Hz), 5.30 (1H, d, *J* = 10.5 Hz), 2.35 (3H, s), 1.93 (1H, d, *J* = 3.9 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 145.2, 138.8, 135.8, 135.5, 130.1, 129.0, 127.1, 125.1, 124.2, 123.5, 123.4, 120.7, 116.6, 113.9, 69.1, 21.8. HRMS (FAB) calcd. for $C_{18}H_{17}NO_3S$: 327.0929, found: 327.0940.

(*E*)-1-(1-tosyl-1*H*-indol-3-yl)non-2-en-1-ol (**38b**). Followed procedure given for **20** (Step 1), with 1 mL (5.9 mmol) (*E*)-1-iodooct-1-ene,[6] 3.0 mL (4.8 mmol) *n*-butyllithium (1.6M in hexanes), 1.2 g (4.0 mmol) 1-tosyl-1*H*-indole-3-carbaldehyde,[7] and 20 mL THF. Purified via silica gel chromatography (6:4 pentane:ether) to obtain 500.8 mg of **38b** as a sticky yellow substance (30% yield). Significant decomposition of **38b** was observed within ca. 1 week. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.98 (1H, d, *J* = 8.1 Hz), 7.78 (2H, d, *J* = 8.4 Hz), 7.62 (1H, d, *J* = 7.8 Hz), 7.53 (1H, d, *J* = 0.9 Hz), 7.3 (4H, m), 5.8 (2H, m), 5.39 (1H, m), 2.35 (3H, s), 2.08 (2H, dt, *J* = 6.7, 6.7 Hz), 1.84 (1H, d, *J* = 4.2 Hz), 1.35 (8H, m), 0.89 (3H, t, *J* = 7.2 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 145.1, 135.8, 135.5, 134.4, 130.7, 130.1, 129.2, 127.1, 125.02, 124.97, 123.3, 123.1, 120.8, 113.9, 69.3, 32.4, 31.9, 29.2, 29.1, 22.8, 21.8, 14.3. HRMS (EI) calcd. for $C_{24}H_{29}NO_3S$: 411.1868, found: 411.1864.

(*E*)-3-(1-tosyl-1*H*-indol-3-yl)prop-2-en-1-ol (**39a**). Followed procedure given for **21**, with 131 mg (0.4 mmol) **38a**, 3 mg (0.006 mmol) **1**, 2 mL THF, a reaction temperature of –50 °C, and a reaction time of 10 minutes. Purified via silica gel chromatography (2:1 pentane:ether) to obtain 72.9 mg of **39a** as a fluffy white solid (56% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 8.00 (1H, d, *J* = 8.1 Hz), 7.74 (3H, m), 7.59 (1H, s), 7.30 (2H, m), 7.19 (2H, d, *J* = 8.1 Hz), 6.68 (1H, dd, *J* = 16.1, 0.8 Hz), 6.44 (1H, dt, *J* = 16.2, 5.6 Hz), 4.35 (2H, dd, *J* = 5.7, 1.2 Hz), 2.31 (3H, s), 1.83 (1H, br). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 145.2, 135.7, 135.2, 130.1, 130.0, 129.2, 127.0, 125.1, 124.2, 123.7, 121.8, 120.5, 120.2, 113.9, 64.0, 21.7. HRMS (FAB) calcd. for $C_{18}H_{17}NO_3S$: 327.0929, found: 327.0933.

(*E*)-1-(1-tosyl-1*H*-indol-3-yl)non-1-en-3-ol (**39b**). Followed procedure given for **21**, with 82.2 mg (0.2 mmol) **38b**, 2 mg (0.004 mmol) **1**, 1 mL ether, a reaction temperature of –50 °C, and a reaction time of 30 minutes. Purified via silica gel chromatography (6:4 pentane:ether) to obtain 54.3 mg of **39b** as a yellow oil (66% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.69 (1H, d, *J* = 8.1 Hz), 7.4 (3H, m), 6.95 (3H, m), 6.82 (2H, d, *J* = 7.8 Hz), 6.32 (1H, d, *J* = 16.2 Hz), 5.99 (1H, dd, *J* = 16.1, 6.8 Hz), 3.98 (1H, dt, *J* = 6.2, 6.2 Hz), 1.95 (3H, s) 1.95 (1H, br), 1.2 (10H, m), 0.57 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 145.1, 135.6, 135.1, 134.2, 130.0, 129.1, 126.9, 125.0, 124.0, 123.6, 120.7, 120.5, 120.2, 113.8, 73.4, 37.6, 31.9, 29.4, 25.6, 22.7, 21.6, 14.2. HRMS (FAB) calcd. for $C_{24}H_{29}NO_3S$: 411.1868, found: 411.1852.

2-Hydroxy-but-3-ene nitrile (**40a**). To a suspension of 2 mg of zinc iodide (0.006 mmol) in 3 mL of freshly distilled propenal (44.9 mmol) in a 50 mL round bottom flask under argon was added 6.55 mL of trimethylsilyl cyanide (49.3 mmol). An exotherm was observed and the resulting yellow solution was stirred for 16 h at room temperature. The solution was diluted with 20 mL THF and 20 mL of 1 M aqueous HCl was added. The solution was stirred vigorously for 1 h and the organic layer separated and concentrated by distillation of the THF at atmospheric pressure. The resulting oil was distilled by kugelrohr to yield 814 mg of **40a** (22%) as a clear liquid. NMR spectral data agreed with that previously reported in the literature.[8] bp 60 ^{o}C ABT / 0.5 mmHg. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.95 (1H, ddd, *J* = 17.1, 10.4, 5.2 Hz), 5.64 (1H, dd, *J* = 17.5, 1.4 Hz), 5.46 (1H, dd, *J* = 10.2,

1.2 Hz), 5.0 (1H, bs), 3.2 (1H, bs). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 131.79, 120.34, 118.17, 62.18.

(*E*)-2-Hydroxy-pent-3-ene nitrile (**40b**). To a suspension of 2 mg of zinc iodide (0.006 mmol) in 3.7 mL of crotonaldehyde (44.9 mmol) in a 50 mL round bottom flask under argon was added 6.55 mL of trimethylsilyl cyanide (49.3 mmol). An exotherm was observed and the resulting yellow solution was stirred for 16 h at room temperature. The solution was diluted with 20 mL THF and 20 mL of 1 M aqueous HCl was added. The solution was stirred vigorously for 1 h and the organic layer separated and concentrated by distillation of the THF at atmospheric pressure. The resulting oil was distilled by kugelrohr to yield 2.28 of **40b** (48%) as a clear liquid. NMR spectral data agreed with that previously reported in the literature.[8] bp 80 ^{o}C ABT / 0.5 mmHg. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 6.05 (1H, dqd, *J* = 15.2, 6.6, 1.1 Hz), 5.60 (1H, ddq, *J* = 15.4, 6.1, 1.6 Hz), 4.91 (1H, bs), 3.38 (1H, bs), 1.76 (3H, m). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 133.05, 125.08, 118.77, 61.77, 17.67.

2-Hydroxy-4-methyl-pent-3-ene nitrile (**40c**). To a suspension of 2 mg of zinc iodide (0.006 mmol) in 3 mL of 3-methyl but-2-enal (30.9 mmol) in a 50 mL round bottom flask under argon was added 4.1 mL of trimethylsilyl cyanide (30.9 mmol). An exotherm was observed and the resulting yellow solution was stirred for 16 h at room temperature. The solution was diluted with 20 mL THF and 20 mL of 1 M aqueous HCl was added. The solution was stirred vigorously for 1 h and the organic layer separated. The aqueous layer was extracted with diethyl ether (2 x 50 mL) and the combine organic layers dried over

Na_2SO_4. After filtration and concentration, the residue was purified by silica gel column chromatography (7:1 hexane/EtOAc) to yield 1.73 g (52%) of **40c** as a clear liquid. NMR spectral data agreed with that previously reported in the literature.[9] ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.37 (1H, d, *J* = 8.5 Hz), 5.10 (1H, d, *J* = 8.5 Hz), 3.09 (1H, bs), 1.79 (3H, s) 1.75 (3H, s). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 142.14, 119.16, 119.52, 58.04, 25.71, 18.53.

(*E*)-4-Hydroxy-3-methyl pent-2-ene nitrile (**41c**). Followed procedure given for **21**, with 100 mg of **40c** (0.9 mmol), 11 mg of **1** (0.022 mmol), 5 mL toluene, a reaction temperature of 23 ^{o}C, and a reaction time of 5 min. Purified via silica gel chromatography (5:1 hexane/EtOAc) to obtain 83 mg of **41c** as a clear oil (83%). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 6.78 (1H, d, *J* = 16.3 Hz), 5.65 (1H, d, *J* = 16.3 Hz), 1.81 (1H, s), 1.25 (6H, s). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 161.2, 117.6, 97.3, 71.4, 29.3. IR (thin film): 3435, 2979, 2228, 1635, 1467, 1366, 1234, 1170. HRMS (EI) calcd. for C_6H_8NO: 111.0606, found: 111.0608.

(*E*)-3-cyclohexylbut-2-en-1-ol (**43a**). In glove box, 6.6 mg of **1** (0.0125 mmol) was added to a 2-necked, 25 mL round bottom flask fitted with a septum and stopcock adapter. The flask was then removed from the glove box, 20 mg of *N*-trimethylsilyl-acetamide (0.125 mmol) and 4 mL Et_2O were added to it. The solution was stirred for 10 minutes at 0 ^{o}C prior to addition of 140 μL of *N*,*O*-bis(trimethylsilyl)-acetamide[10] (0.64 mmol) followed by 100 mg of **42a** (0.64 mmol)**.** The reaction quickly turned from yellow to deep purple and it was allowed to stir at 0 ^{o}C for 30 minutes prior to addition of 40 μL of triethylamine.

Removed ice bath and allowed solution to stir at room temperature for approximately 10 minutes before concentration. The residue was then dissolved in 5 mL MeOH and 220 mg K_2CO_3 (0.8 mmol) was added. Stirred suspension vigorously for 1 h prior to addition of 10 mL aqueous NH_4Cl solution, extraction with CH_2Cl_2 (2 x 25 mL) and drying over Na_2SO_4. The residue was purified via silica gel chromatography (8:2 hexane:ether) to yield 84 mg of **43a** as a clear oil (84% yield). NMR spectral data agreed with that previously reported in the literature.[2] ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.38 (1H, t, *J* = 6.8 Hz), 4.15 (2H, d, *J* = 6.6 Hz), 1.7 (7H, m), 1.64 (3H, s), 1.2 (5H, m). ^{13}C NMR (300 MHz, $CDCl_3$, ppm): δ 144.9, 121.7, 59.6, 47.3, 31.9, 26.8, 26.5, 14.8. HRMS (EI) calcd. for $C_{10}H_{18}O$: 154.1358, found: 154.1352.

3-methylhept-2-en-1-ol (**43b**). Followed procedure given for **43a**, with 3.3 mg of **1** (0.0064 mmol), 10 mg of *N*-trimethylsilyl-acetamide (0.064 mmol), 70 μL of *N*,*O*-bis(trimethylsilyl)-acetamide[10] (0.32 mmol) and 41 mg of **42b** (0.32 mmol) in 2 mL ether at 0 ^{o}C for 30 minutes. Purified via silica gel chromatography (7:3 hexane:ether) to obtain 38 mg of **43b** as a clear oil (93% yield). NMR spectral data agreed with that previously reported in the literature.[2] **(*E*-isomer)**. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.40 (1H, td, *J* = 6.9, 0.9 Hz), 4.15 (2H, d, *J* = 6.9 Hz), 2.01 (2H, t, *J* = 7.4 Hz), 1.67 (3H, s), 1.3 (5H, m), 0.90 (3H, t, *J* = 7.1 Hz). ^{13}C NMR (300 MHz, $CDCl_3$, ppm): δ 140.4, 123.3, 59.6, 39.4, 30.1, 22.6, 16.3, 14.2. HRMS (EI) calcd. for $C_8H_{16}O$: 128.1201, found: 128.1195. **(*Z*-isomer)**. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.42 (1H, tt, *J* = 7.1, 0.8 Hz), 4.13 (2H, dd, *J* = 7.2, 0.9 Hz), 2.08 (2H, t, *J* = 7.4 Hz), 1.74 (3H, dt, *J* = 1.1, 1.1 Hz), 1.35 (5H, m),

0.91 (3H, t, J = 7.1 Hz). ^{13}C NMR (300 MHz, $CDCl_3$, ppm): δ 140.8, 124.1, 59.3, 31.9, 30.7, 23.7, 22.8, 14.2. HRMS (EI) calcd. for $C_8H_{16}O$: 128.1201, found: 128.1195.

(*E*)-3,4,4-trimethylpent-2-en-1-ol (**43c**). Followed procedure given for **43a**, with 16 mg of **1** (0.032 mmol), 20 mg of *N*-trimethylsilyl-acetamide (0.013 mmol), 140 μL of *N*,*O*-bis(trimethylsilyl)-acetamide[10] (0.64 mmol) and 84 mg of **42c** (0.64 mmol) in 4 mL ether at 0 ^{o}C for 60 minutes. Purified via silica gel chromatography (8:2 hexane:ether) to obtain 69 mg of **43c** as a clear oil (82% yield). NMR spectral data agreed with that previously reported in the literature.[2] ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.45 (1H, tq, J = 6.5, 1.1 Hz), 4.19 (2H, dd, J = 6.5, 0.8 Hz), 1.66 (3H, m), 1.45 (1H, br), 1.05 (9H, s). ^{13}C NMR (300 MHz, $CDCl_3$, ppm): δ 147.3, 120.6, 60.2, 36.3, 29.0, 13.0. HRMS (EI) calcd. for $C_8H_{16}O$: 128.1201, found: 128.1207.

3-Phenylpent-1-en-3-ol (**44b**). Followed procedure given for **34a**, with 11 mL (83 mmol) propiophenone, 100 mL (100 mmol) vinylmagnesium bromide (1.0M in THF), and 100 mL ether. Purified twice via silica gel chromatography (8:2 pentane:ether; then 9:1 pentane:ether) to obtain 8.14 g of **44b** as an oil (60% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.39 (2H, m), 7.25 (2H, m), 7.18 (1H, m), 6.12 (1H, dd, J = 17.3, 10.7 Hz), 5.22 (1H, dd, J = 17.3, 1.1 Hz), 5.09 (1H, dd, J = 10.8, 1.2 Hz), 1.85 (2H, m), 1.79 (1H, br), 0.77 (3H, t, J = 7.4 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 145.6, 144.3, 128.4, 127.0, 125.6, 112.9, 34.8, 8.1. HRMS (EI) calcd. for $C_{11}H_{14}O$: 162.1045, found: 162.1049.

3-phenylbut-2-en-1-ol (**45a**). Followed procedure given for **43a**, with 6.6 mg of **1** (0.00125 mmol), 20 mg of *N*-trimethylsilyl-acetamide (0.13 mmol), 140 μL of *N*,*O*-bis(trimethylsilyl)-acetamide[10] (0.65 mmol) and 96 mg of **44a** (0.65 mmol) in 4 mL ether at -10 ^{o}C for 30 minutes. Purified via silica gel chromatography (8:2 hexane:ether) to obtain 81 mg of **45a** as a clear oil (84% yield). NMR spectral data agreed with that previously reported in the literature.[2] **(*E*-isomer)**. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.45 (2H, m), 7.34 (3H, m), 6.01 (1H, dt, *J* = 6.68, 1.4 Hz), 4.40 (2H, d, *J* = 6.6 Hz), 2.12 (3H, s), 1.74 (1H, br). ^{13}C NMR (300 MHz, $CDCl_3$, ppm): δ 143.0, 138.0, 128.5, 127.5, 126.7, 126.0, 60.1, 16.2. HRMS (EI) calcd. for $C_{10}H_{12}O$: 148.0888, found: 148.0887. **(*Z*-isomer)**. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.35 (3H, m), 7.21 (2H, m), 5.74 (1H, dt, *J* = 7.05, 1.3 Hz), 4.10 (2H, dd, *J* = 6.9, 1.2 Hz), 2.12 (3H, s), 1.53 (1H, br). ^{13}C NMR (300 MHz, $CDCl_3$, ppm): δ 141.0, 140.4, 128.3, 127.9, 127.4, 126.3, 60.5, 25.5. HRMS (EI) calcd. for $C_{10}H_{12}O$: 148.0888, found: 148.0891.

(*E*)-3-phenylpent-2-en-1-ol (**45b**). Followed procedure given for **43a**, with 6.6 mg of **1** (0.00125 mmol), 20 mg of *N*-trimethylsilyl-acetamide (0.13 mmol), 140 μL of *N*,*O*-bis(trimethylsilyl)-acetamide[10] (0.65 mmol) and 105 mg of **44b** (0.65 mmol) in 4 mL ether at -10 ^{o}C for 30 minutes. Purified via silica gel chromatography (8:2 hexane:ether) to obtain 82 mg of **45b** as a clear oil (78% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.45 (5H, m), 5.96 (1H, t, *J* = 6.9 Hz), 4.47 (2H, d, *J* = 6.9 Hz), 2.66 (2H, dt, *J* = 7.5, 7.5 Hz), 1.85 (1H, br), 1.11 (3H, t, *J* = 7.5 Hz). The following minor peaks correspond to the *Z*-isomer: δ 7.22 (d), 5.79 (tt, *J* = 6.9, 1.4 Hz), 4.16 (d, *J* = 6.9 Hz), 2.5 (dt). ^{13}C NMR (75.4

MHz, $CDCl_3$, ppm): δ 145.0, 142.1, 128.5, 127.4, 126.6, 126.4, 59.8, 23.4, 14.1. HRMS (EI) calcd. for $C_{11}H_{14}O$: 162.1045, found: 162.1043.

(*E*)-5-methyltridec-6-en-5-ol (**46a**). To a flame-dried, round-bottomed flask, under an argon atmosphere, added hept-1-en-3-ol (1 mL, 7.8 mmol), 1-octene (2.5 mL, 15.9 mmol), and 40 mL CH_2Cl_2. Then added, via cannula transfer, a solution of $RuCl_2(PCy_3)(H_2IMes)CHPh$ (300 mg, 0.35 mmol) and 5 mL CH_2Cl_2. Placed in a 45 °C oil bath and let stir overnight. Allowed to cool to room temperature, removed solvent *in vacuo*, and purified three times via silica gel chromatography (9:1 pentane:ether; then 7:3 pentane:ether; then 8:2 pentane:ether) to obtain 913 mg g of **46a** as a yellow oil (55% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.60 (1H, dt, *J* = 15.6, 6.2 Hz), 5.50 (1H, d, *J* = 15.6 Hz), 2.03 (2H, dt, *J* = 6.7, 6.7 Hz), 1.4 (14H, m), 1.26 (3H, s), 0.90 (3H, t, *J* = 6.9 Hz), 0.89 (3H, t, *J* = 6.9 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 137.2, 128.2, 73.0, 42.8, 32.5, 31.9, 29.6, 29.0, 28.2, 26.5, 23.4, 22.9, 14.3. HRMS (EI) calcd. for $C_{14}H_{28}O$: 212.2140, found: 212.2130.

(*E*)-2,2,3-trimethylundec-4-en-3-ol (**46b**). Followed the procedure given for **46a**, with 4,4-dimethylpent-1-en-3-ol (1 mL, 8.58 mmol), 1-octene (2.7 mL, 17.2 mmol), $RuCl_2(PCy_3)(H_2IMes)CHPh$ (300 mg, 0.35 mmol) and 40 mL CH_2Cl_2. Purified twice via silica gel chromatography (9:1 pentane:ether; then 7:3 pentane:ether) to obtain 1.07 g of **46b** as a yellow-gold oil (59% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.67 (1H, d, *J* = 15.6 Hz), 5.59 (1H, dt, *J* = 15.6, 5.9 Hz), 2.05 (2H, dt, *J* = 6.7, 6.7 Hz), 1.57 (1H, br), 1.3 (8H, m), 1.24 (3H, s), 0.94 (9H, s), 0.89 (3H, t, *J* = 7.1 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$,

ppm): δ 135.1, 128.8, 77.0, 37.6, 32.7, 31.9, 29.7, 29.1, 25.6, 23.8, 22.9, 14.3. HRMS (EI) calcd. for $C_{14}H_{28}O$ – H: 211.2056, found: 211.2065.

5-Methyltridec-5-en-7-ol (**47a**). Followed procedure given for **43a**, with 6.6 mg of **1** (0.0048 mmol), 7 mg of *N*-trimethylsilyl-acetamide (0.05 mmol), 54 μL of *N*,*O*-bis(trimethylsilyl)-acetamide[10] (0.24 mmol) and 50 mg of **46a** (0.24 mmol) in 2 mL ether at 23 ^{o}C for 30 minutes. Purified via silica gel chromatography (9:1 hexane:ether) to obtain 29 mg of **47a** as a clear oil (58% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.16 (1H, d, *J* = 9.2 Hz), 4.36 (1H, m), 2.09 (*Z*-isomer, 0.6H, dt, *J* = 7.0, 7.0 Hz), 2.01 (*E*-isomer, 1.4H, t, *J* = 7.1 Hz), 1.72 (*Z*-isomer, 1H, d, *J* = 1.5 Hz), 1.68 (*E*-isomer, 2H, d, *J* = 1.2 Hz), 1.37 (14H, m), 0.92 (6H, m). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 139.6, 139.1, 128.8, 128.1, 68.9, 68.5, 39.5, 38.03, 38.00, 32.2, 32.1, 30.8, 30.1, 29.5, 25.74, 25.67, 23.6, 23.0, 22.85, 22.83, 22.5, 16.7, 14.3, 14.23, 14.19. HRMS (EI) calcd. for $C_{14}H_{28}O$: 212.2140, found: 212.2141.

(*E*)-2,2,3-trimethylundec-3-en-5-ol (**47b**). Followed procedure given for **43a**, with 6.6 mg of **1** (0.0048 mmol), 7 mg of *N*-trimethylsilyl-acetamide (0.05 mmol), 54 μL of *N*,*O*-bis(trimethylsilyl)-acetamide[10] (0.24 mmol) and 50 mg of **46b** (0.24 mmol) in 2 mL ether at 23 ^{o}C for 24 hours. Purified via silica gel chromatography (9:1 hexane:ether) to obtain 13 mg of **47b** as a clear oil (26% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.23 (1H, dd, *J* = 8.4, 1.2 Hz), 4.37 (1H, m), 1.69 (3H, d, *J* = 0.9 Hz), 1.29 (10H, m), 1.05 (9H, s), 0.89 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 146.5, 125.2, 69.3, 38.1,

36.3, 32.1, 29.5, 29.2, 25.7, 22.8, 14.3, 13.3. HRMS (EI) calcd. for $C_{14}H_{28}O$: 212.2140, found: 212.2131.

(*R*,*E*)-1-(4-(trifluoromethyl)phenyl)non-2-en-1-ol ((*R*,*E*)-**20**). *Step 1*: Same reaction as for **20** (Step 1). *Step 2*: Same reaction as for **20** (Step 2). *Step 3*: 1 mL (3.9 mmol) 1-(4-(trifluoromethyl)phenyl)non-2-yn-1-one, 12 mL (12 mmol) (*S*)-2-methyl-CBS-oxazaborolidine (1.0M in toluene), 10 mL (20 mmol) borane-methyl sulfide complex (2.0M in THF), 400 mg 4 Å molecular sieves (pellets), and 30 mL THF. Purified via silica gel chromatography (7:3 pentane:ether) to obtain 1.08 g of (*S*)-1-(4-(trifluoromethyl)-phenyl)non-2-yn-1-ol as a yellow oil (97% yield). Enantiomeric excess determined to be >99% by chiral HPLC (AD column, 2% *i*-PrOH in hexanes, 1 mL/min, 220 nm). *Step 4*: 1.06 g (3.7 mmol) (*S*)-1-(4-(trifluoromethyl)-phenyl)non-2-yn-1-ol (>99% ee), 11 mL (11 mmol) lithium aluminum hydride (1.0M in THF), 30 mL THF, and a reaction time of 70.5 hours. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 813 mg of (*R*,*E*)-**20** as a yellow oil (77%). Spectral data same as for **20**. Enantiomeric excess determined to be >99% by chiral HPLC (OB-H column, 1% *i*-PrOH in hexanes, 1 mL/min, 220 nm). $[\alpha]_D = -42.38$ (24 °C, $CHCl_3$, c = 1.0).

(*R*,*E*)-1-(4-(trifluoromethyl)phenyl)non-1-en-3-ol ((*R*,*E*)-**21**). Followed procedure given for **21**, with 114.3 mg (0.4 mmol) (*R*,*E*)-**20**, 6 mg (0.012 mmol) **1**, 2 mL ether, a reaction temperature of –50 °C, and a reaction time of 1 hour. Purified via silica gel chromatography (8:2 pentane:ether) to obtain ca. 114 mg of (*R*,*E*)-**21** as a waxy solid (99% yield). Spectral data same as for **21**. Enantiomeric excess determined to be 95% by chiral

HPLC (OD-H column, 1% *i*-PrOH in hexanes, 1 mL/min).). $[\alpha]_D$ = –7.7 (24 °C, $CHCl_3$, c = 1.0).

(*R*,*E*)-1-(4-methoxyphenyl)non-2-en-1-ol ((*R*,*E*)-**22b**). *Step 1*: Same reaction as for **22b** (Step 1). *Step 2*: To a flame-dried, round-bottomed flask, under an argon atmosphere, added 1-(4-methoxyphenyl)non-2-yn-1-ol (3 mL, 13 mmol), 85% manganese(IV) oxide (13.3 g, 130 mmol), and benzene (130 mL). Let stir at room temperature for 72 hours, then filtered through Celite, rinsing with ether. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 2.69 g of 1-(4-methoxyphenyl)non-2-yn-1-one[11] as a pale yellow oil (85% yield). *Step 3*: To a 3-neck, round-bottomed flask, added 4 Å molecular sieves (pellets, 400 mg) and flame-dried under vacuum. Let cool to room temperature, placed under an argon atmosphere, added 1-(4-methoxyphenyl)non-2-yn-1-one (1 mL, 4.1 mmol) and THF (30 mL). Let stir at room temperature for 3 hours. Added a 1.0M toluene solution of (*S*)-2-methyl-CBS-oxazaborolidine (8 mL, 8 mmol) and placed in a dry ice ethylene glycol:ethanol (8:2) bath. (Note: cold bath becomes solid, so flask should be placed in bath prior to dry ice addition.) When temperature was between –30 to –40 °C, added a 2.0M THF solution of borane-methyl sulfide complex (10 mL, 20 mmol) dropwise, over approximately 15 minutes. Let stir at –30 to –40 °C for 3 hours, then, *very* slowly, added 40 mL MeOH and let warm to room temperature. Diluted with 150 mL ether, washed twice with 75 mL aqueous NH_4Cl solution, twice with 75 mL aqueous $NaHCO_3$ solution, and twice with 75 mL brine, then dried with Na_2SO_4. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 550 mg of (*S*)-1-(4-methoxyphenyl)non-2-yn-1-ol as an oil (54% yield). Enantiomeric excess determined to be 92% by chiral

HPLC (OD-H column, 4% *i*-PrOH in hexanes, 1 mL/min, 220 nm). *Step 4*: Followed procedure given for **22b** (Step 2), with 543 mg (2.2 mmol) (*S*)-1-(4-methoxyphenyl)non-2-yn-1-ol (92% ee), 7 mL (7 mmol) lithium aluminum hydride (1.0M in THF), 20 mL THF, and a reaction time of 68 hours. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 439 mg of (*R*,*E*)-**22b** as a yellow oil (80%). Spectral data same as for **22b**. Enantiomeric excess determined to be 89% by chiral HPLC (OD-H column, 3% *i*-PrOH in hexanes, 1 mL/min, 220 nm). $[\alpha]_D = -5.78$ (23 °C, $CHCl_3$, c = 1.0).

(*R*,*E*)-1-(4-methoxyphenyl)non-1-en-3-ol ((*R*,*E*)-**23b**). Followed procedure given for **21**, with 99.4 mg (0.4 mmol) (*R*,*E*)-**22b**, 6 mg (0.012 mmol) **1**, 2 mL ether, a reaction temperature of –78 °C, and a reaction time of 2 hours. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 72.0 mg of (*R*,*E*)-**23b** as a clear oil (72% yield). Spectral data same as for **23b**. Enantiomeric excess determined to be 1% by chiral HPLC (OD-H column, 4% *i*-PrOH in hexanes, 1 mL/min).

(*R*,*E*)-3-methyl-1-phenylnon-2-en-1-ol ((*R*,*E*)-**50**). *Step 1*: To a flame-dried, round-bottomed flask, under an argon atmosphere, added bis(cyclopentadienyl)-zirconium dichloride (790 mg, 2.70 mmol), a 2.0M hexanes solution of trimethylaluminum (20 mL, 40 mmol), and CH_2Cl_2 (70 mL). Placed in water/ice/NH_4Cl bath (approximately –10 °C) and *slowly* added water (365 μL, 20.3 mmol) via syringe. Let stir for 10 minutes. Added a solution of 1-octyne (2 mL, 13.5 mmol) and CH_2Cl_2 (10 mL) dropwise, over 5 minutes. Let stir at ca. –10 °C for 10 minutes, then added a solution of iodine (4.1 g, 16.2 mmol) and THF (20 mL) dropwise, over 10 minutes. Let stir at ca. –10 °C for 15 minutes, then

removed cold bath and let slowly warm to room temperature. *Very slowly* added 5 mL aqueous K_2CO_3 solution, let stir for 15 minutes, then added $MgSO_4$ and filtered, rinsing with ether. Purified via silica gel chromatography (100% hexanes) to obtain 2.81 g of (*E*)-1-iodo-2-methyloct-1-ene[12] as a slightly yellow oil (83% yield). *Step 2*: Followed procedure given for **20** (Step 1), with 1 mL (5.2 mmol) (*E*)-1-iodo-2-methyloct-1-ene, 3.2 mL (5.1 mmol) *n*-butyllithium (1.6M in hexanes), 0.5 mL (4.9 mmol) benzaldehyde (distilled from CaH_2), and 25 mL ether. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 820 mg of (*E*)-3-methyl-1-phenylnon-2-en-1-ol[13] as an oil (72% yield). *Step 3*: Followed procedure given for (*R*,*E*)-**21b** (Step 2), with: 903 mg (3.9 mmol) (*E*)-3-methyl-1-phenylnon-2-en-1-ol, 4.0 g (39 mmol) manganese(IV) oxide (85%), 40 mL benzene, and a reaction time of 71 hours. Purified via silica gel chromatography (9:1 pentane:ether) to obtain 593 mg of (*E*)-3-methyl-1-phenylnon-2-en-1-one[14] as a yellow oil (66% yield). *Step 4*: Followed procedure given for (*R*,*E*)-**21b** (Step 3), with 571 mg (2.48 mmol) (*E*)-3-methyl-1-phenylnon-2-en-1-one, 5 mL (5 mmol) (*S*)-2-methyl-CBS-oxazaborolidine (1.0M in toluene), 6 mL (12 mmol) borane-methyl sulfide complex (2.0M in THF), 250 mg 4 Å molecular sieves (pellets), and 20 mL THF. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 497 mg of (*R*,*E*)-**50** as a yellow oil (86% yield). NMR spectral data agreed with that previously reported in the literature.[13] Enantiomeric excess determined to be 99% by chiral HPLC (OD-H column, 1% *i*-PrOH in hexanes, 1 mL/min, 220 nm). $[\alpha]_D = -82.0$ (24 °C, $CHCl_3$, c = 0.94).

(*R*,*E*)-3-methyl-1-phenyldec-1-en-3-ol ((*R*,*E*)-**51**). Followed procedure given for **21**, with 92.8 mg (0.4 mmol) (*R*,*E*)-**50**, 8 mg (0.016 mmol) **1**, 2 mL THF, a reaction temperature of

–78 °C, and a reaction time of 2 hours. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 74.8 mg of (*R*,*E*)-**51** as a clear oil (81% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.3 (5H, m), 6.58 (1H, d, *J* = 15.9 Hz), 6.28 (1H, d, *J* = 16.2 Hz), 1.6 (3H, m), 1.38 (3H, s), 1.3 (8H, m), 0.88 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 137.3, 137.1, 128.8, 127.5, 127.2, 126.6, 73.5, 43.2, 32.0, 29.9, 28.4, 24.2, 22.8, 14.2. HRMS (EI) calcd. for $C_{17}H_{26}O$ $-CH_2$: 232.1827, found: 232.1818. Enantiomeric excess determined to be 9% by chiral HPLC (OJ column, 1% *i*-PrOH in hexanes, 1 mL/min).

(*R*,*E*)-3-methyl-1-(4-(trifluoromethyl)phenyl)non-2-en-1-ol ((*R*,*E*)-**52**). Followed procedure given for (*R*,*E*)-**50**, with: *Step 1*: Same reaction. *Step 2*: 1.4 mL (6.7 mmol) (*E*)-1-iodo-2-methyloct-1-ene, 4 mL (6.4 mmol) *n*-butyllithium (1.6M in hexanes), 750 μL (5.6 mmol) α,α,α-trifluoro-*p*-tolualdehyde, and 40 mL ether. Purified via silica gel chromatography (9:1 to 8:2 pentane:ether) to obtain 1.46 g of (*E*)-3-methyl-1-(4-(trifluoromethyl)-phenyl)non-2-en-1-ol as a yellow oil (87% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.60 (2H, d, *J* = 8.1 Hz), 7.50 (2H, d, *J* = 8.7 Hz), 5.55 (1H, dd, *J* = 8.7, 3.3 Hz), 5.36 (1H, dq, *J* = 8.9, 1.3 Hz), 2.04 (2H, t, *J* = 7.7 Hz), 1.82 (3H, d, *J* = 1.5 Hz), 1.82 (1H, m), 1.35 (8H, m), 0.88 (3H, t, *J* = 6.6 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 148.4 (d, *J* = 4.5 Hz), 140.5, 129.5 (q, *J* = 128 Hz), 126.8, 126.3, 125.5 (q, *J* = 15.1 Hz), 124.4 (q, *J* = 1081 Hz), 70.2, 39.7, 31.9, 29.1, 27.8, 22.8, 16.9, 14.2. HRMS (EI) calcd. for $C_{17}H_{23}F_3O$: 300.1701, found: 300.1709. *Step 3*: 810 mg (2.7 mmol) (*E*)-3-methyl-1-(4-(trifluoromethyl)phenyl)non-2-en-1-ol, 2.6 g (25 mmol) manganese(IV) oxide (85%), 50 mL benzene, and a reaction time of 65.5 hours. Purified via silica gel chromatography (9:1

pentane:ether) to obtain 602 mg of (*E*)-3-methyl-1-(4-(trifluoromethyl)phenyl)non-2-en-1-one as a yellow oil (75% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 8.02 (2H, d, *J* = 8.1 Hz), 7.72 (2H, d, *J* = 8.4 Hz), 6.73 (1H, q, *J* = 1.2 Hz), 2.29 (2H, t, *J* = 7.7 Hz), 2.24 (3H, d, *J* = 1.2 Hz), 1.48 (8H, m), 0.91 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 190.5, 163.2, 142.5, 133.7 (q, *J* = 129 Hz), 128.6, 125.7 (q, *J* = 14.7 Hz), 120.1, 124.0 (q, *J* = 1084 Hz), 41.9, 31.9, 29.2, 27.8, 22.8, 20.2, 14.3. HRMS (EI) calcd. for $C_{17}H_{21}F_3O$: 298.1544, found: 298.1558. *Step 4*: 582 mg (1.95 mmol) (*E*)-3-methyl-1-(4-(trifluoromethyl)phenyl)non-2-en-1-one, 4 mL (4 mmol) (*S*)-2-methyl-CBS-oxazaborolidine (1.0M in toluene), 5 mL (10 mmol) borane-methyl sulfide complex (2.0M in THF), 200 mg 4 Å molecular sieves (pellets), and 20 mL THF. Purified via silica gel chromatography (8:2 pentane:ether) to obtain 524 mg of (*R*,*E*)-**52** as a slightly yellow oil (89% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.60 (2H, d, *J* = 8.1 Hz), 7.50 (2H, d, *J* = 8.7 Hz), 5.55 (1H, dd, *J* = 8.7, 3.3 Hz), 5.36 (1H, dq, *J* = 8.9, 1.3 Hz), 2.04 (2H, t, *J* = 7.7 Hz), 1.82 (3H, d, *J* = 1.5 Hz), 1.82 (1H, m), 1.35 (8H, m), 0.88 (3H, t, *J* = 6.6 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 148.4 (d, *J* = 4.5 Hz), 140.5, 129.5 (q, *J* = 128 Hz), 126.8, 126.3, 125.5 (q, *J* = 15.1 Hz), 124.4 (q, *J* = 1081 Hz), 70.2, 39.7, 31.9, 29.1, 27.8, 22.8, 16.9, 14.2. HRMS (EI) calcd. for $C_{17}H_{23}F_3O$: 300.1701, found: 300.1709. Enantiomeric excess determined to be 93% by chiral HPLC (OJ column, 1% *i*-PrOH in hexanes, 1 mL/min, 220 nm). $[\alpha]_D$ = –82.2 (24 °C, $CHCl_3$, c = 1.1).

(*R*,*E*)-3-methyl-1-(4-(trifluoromethyl)phenyl)non-1-en-3-ol ((*R*,*E*)-**53**). Followed procedure given for **21**, with 120.1 mg (0.4 mmol) (*R*,*E*)-**52**, 4 mg (0.008 mmol) **1**, 2 mL ether, a reaction temperature of –50 °C, and a reaction time of 30 minutes. Purified via

silica gel chromatography (8:2 pentane:ether) to obtain 114.6 mg of (*R*,*E*)-**53** as a light yellow oil (95% yield). ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.56 (2H, d, *J* = 8.4 Hz), 7.46 (2H, d, *J* = 8.4 Hz), 6.65 (1H, d, *J* = 15.9 Hz), 6.39 (1H, d, *J* = 15.9 Hz), 1.93 (1H, d, *J* = 0.6 Hz), 1.65 (2H, m), 1.41 (3H, s), 1.35 (8H, m), 0.89 (3H, t, *J* = 6.9 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 140.8, 139.7, 129.3 (q, *J* = 129 Hz), 126.7, 126.0, 125.6 (q, *J* = 15.3 Hz), 124.4 (q, *J* = 1081 Hz), 73.5, 43.1, 32.0, 30.0, 28.3, 24.2, 22.8, 14.2. HRMS (EI) calcd. for $C_{17}H_{23}F_3O$: 300.1701, found: 300.1708. Enantiomeric excess determined to be 58% by chiral HPLC (OJ column, 1% *i*-PrOH in hexanes, 1 mL/min). $[\alpha]_D$ = +9.5 (25 °C, $CHCl_3$, c = 0.95).

1-(3,5-bis(trifluoromethyl)phenyl)-non-2-yn-1-ol. To a solution of 3.7 mL diethylzinc (12.5 mmol) in 17 mL toluene in a 250 mL round bottom flask fitted with a reflux condenser under argon was added 1.85 mL octyne (12.5 mmol). The solution was heated to reflux for 1 h and then allowed to cool to room temperature. To this was added 1 g (*R*)-BINOL (3.5 mmol) as a solution in 120 mL diethyl ether by cannula followed by 2.6 mL titanium tetraisopropoxide (8.75 mmol). The solution went from yellow to red. After stirring for 1 h at room temperature, 1.44 mL 3,5-bis-trifluoromethyl-benzaldehyde was added and the resultant solution stirred at room temperature for 4 h. The reaction was quenched by slowly pouring into 200 mL of a cold, stirring aqueous solution of NH_4Cl. The resultant opaque yellow solution was suction filtered through a 1" pad of Celite and the organic layer was separated. The aqueous layer was extracted with diethyl ether (2 x 50 mL) and the combine organic layers dried over Na_2SO_4. Concentration on the rotovap at 100 mmHg caused BINOL to precipitate from the concentrated toluene solution. The

solution could be decanted and directly purified by silica gel column chromatography (9:1 hexane/Et_2O) to yield 1.72 g of 1-(3,5-bis(trifluoromethyl)phenyl)-non-2-yn-1-ol (56% yield) as a waxy solid. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 8.01 (2H, s), 7.83 (1H, s), 5.56 (1H, bm), 2.28 (2H, dt, *J* = 7.2, 2.2 Hz), 1.56 (1H, bs), 1.54 (2H, pent, *J* = 7.2 Hz), 1.34 – 1.26 (6H, m), 0.88 (3H, t, *J* = 6.8 Hz) ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ.143.62, 131.92 (q, *J* = 33.5 Hz), 126.82 (m), 125.06 (q, *J* = 272.5 Hz), 121.96 (m), 89.44, 78.61, 63.52, 31.52, 28.52, 28.29, 22.46, 18.71, 13.97. ^{19}F NMR (XX MHz, $CDCl_3$, ppm): δ -63.29. HRMS (EI) calcd. for $C_{17}H_{18}F_6O$: 352.1262, found: 352.1268. Enantiomeric excess determined to be 94.3% by chiral HPLC (OD-H column, 2% *i*-PrOH in hexanes, 1 mL/min, 220 nm).

(*Z*)-1-(3,5-bis(trifluoromethyl)phenyl)-3-methylnon-2-en-1-ol ((*Z*)-**54**). To a suspension of 19.4 mg bis-cyclopentadienyl-titanium dichloride (0.078 mmol) in 6 mL of diethyl ether at 0 ^{o}C in a 50 mL round bottom flask under argon was added dropwise 2.3 mL of a 2.0 M solution of isobutyl magnesium chloride (4.65 mmol). The solution quickly turned gray although most of the Cp_2TiCl_2 did not dissolve. After stirring the solution for 15 min at 0 ^{o}C, a solution of 549 mg of 1-(3,5-bis(trifluoromethyl)phenyl)-non-2-yn-1-ol (1.55 mmol) in 6 mL of diethyl ether was added. The green-gray solution was removed from the ice bath and allowed to stir at room temperature. After 2 h, 29.5 mg of copper(I) iodide followed by 338 μL methyl iodide (3.47 mmol) was added. The resulting brown solution was allowed to stir at room temperature for an additional 2 h. The reaction was then quenched by slowly pouring into 100 mL of a cold, stirring aqueous solution of NH_4Cl. The organic layer was separated and the aqueous layer was extracted with diethyl ether (2

x 50 mL). The combine organic layers were dried over sodium sulfate and filtered through Celite prior to concentration. The crude product was purified by column chromatography on silver nitrate-impregnated silica gel[15] (9:1 hexane / Et_2O) to yield 450 mg of (*Z*)-**54** (75%, 99:1 *Z*:*E*) as a clear oil.[16] Despite this, the purified product contained 4% of (*Z*)-1-(3,5-bis-(trifluoromethyl)phenyl)-non-2-en-1-ol. This impurity could be removed by reverse phase preparative HPLC (30 min, 10 -100 % MeCN in a 0.1% trifluoroacetic acid solution in water), although its presence did not have a noticeable effect on the yield or enantioselectivity of the subsequent isomerization reaction of (*Z*)-**54**. ^{1}H NMR (300 MHz, C_6D_6, ppm): δ 7.80 (2H, s), 7.70 (1H, s), 5.15 (1H, dd, *J* = 8.8, 3.6 Hz), 5.00 (1H, dd, *J* = 8.8, 0.8 Hz), 1.92 (2H, m), 1.48 (3H, s), 1.46 (1H, d, *J* = 3.6 Hz), 1.31 – 1.19 (8H, m), 0.92 (3H, t, *J* = 6.8 Hz). ^{1}H NMR NOESY (400 MHz, C_6D_6): a cross peak was observed between the signal at 5.00 (1H, dd, *J* = 8.8, 0.8 Hz) and the signal at 1.48 (3H, s). ^{13}C NMR (75.4 MHz, C_6D_6, ppm): δ 148.21, 141.35, 132.1 (q, *J* = 32.9 Hz), 127.58, 126.8 (m), 124.4 (q, *J* = 272.8 Hz), 121.4 (sept, *J* = 3.7 Hz), 69.3, 32.74, 32.48, 29.96, 28.74, 25.53, 23.33, 14.59. ^{19}F NMR (282 MHz, C_6D_6, ppm): δ -63.12. HRMS (EI) calcd. for $C_{18}H_{21}F_6O$: 367.1496, found: 367.1496. Enantiomeric excess determined to be 95.4% by chiral HPLC (AD column, 0.1% EtOH in hexanes, 1 mL/min, 220 nm). $[\alpha]_D$ = -87.3 (20 °C, EtOH, c = 1.05). The geometric isomer ratio was determined by GC (DB-WAX Column, 160 ^{o}C Isothermal) with t_r((*Z*)-**54**) = 16.42 min and t_r((*E*)-**54**) = 20.33 min.

(*E*)-1-(3,5-bis(trifluoromethyl)phenyl)-3-methylnon-1-en-3-ol ((*E*)-**55**). Followed procedure given for **21**, with 150 mg of (*Z*)-**54** (0.38 mmol), 4 mg of **1** (0.006 mmol), 2 mL Et_2O, a reaction temperature of -30 ^{o}C, and a reaction time of 30 min. Purified via silica

gel chromatography (8:2 pentane:ether) to obtain 127 mg of (*E*)-**55** as a clear oil (85%). ^{1}H NMR (300 MHz, C_6D_6, ppm): δ 7.61 (1H, s), 7.49 (2H, s), 6.34 (1H, d, *J* = 16.2 Hz), 5.98 (1H, d, *J* = 16.2 Hz), 1.34 - 1.24 (10H, m), 1.11 (3H, s), 1.06 (1H, s), 0.89 (3H, t, *J* = 6.9 Hz). ^{13}C NMR (75.4 MHz, C_6D_6, ppm): δ 141.56, 140.22, 132.59 (q, *J* = 132.4 Hz), 126.71, 125.81 (q, *J* = 272.8 Hz), 125.06, 120.95 (sept, *J* = 3.7 Hz), 73.18, 43.22, 32.53, 30.47, 28.76, 24.49, 23,41, 14.62. ^{19}F NMR (282 MHz, C_6D_6, ppm): δ -63.17. HRMS (FAB) calcd. for $C_{18}H_{21}F_6O$: 367.1496, found: 367.1498. Enantiomeric excess determined to be 90.4% by chiral HPLC (AD column, 1% *i*-PrOH in hexanes, 1 mL/min). $[\alpha]_D$ = -16.5 (20 °C, EtOH, c = 0.97).

(*R*,*E*)-2-Hydroxy-4,8-dimethyl-nona-3,7-diene nitrile (**56**). The procedure was adapted from the literature.[17] To a solution of 2.6 g of potassium cyanide (38.9 mmol) in 20 mL of water at 0 ^{o}C was added sufficient concentrated HCl to attain a pH of 1. This solution was extracted with diisopropyl ether (3 x 15 mL) and the combine extracts kept at 0 ^{o}C. To a second 125 mL Erlenmeyer flask with a stir bar was added 3.6 g almond meal[18] and it was wetted with 5 mL of a 0.02 M pH 5.5 citrate buffer. The resulting paste was pressed against the walls of the flask and 1.1 mL of geranial[19] (6.5 mmol) was dripped over the paste. The flask was then placed in an ice-water bath and the HCN solution in diisopropyl ether was added to it. Sealed flask and stirred gently at 4 ^{0}C for 24 h. The solution was then filtered through a 1" pad of silica gel topped with a 1" pad of magnesium sulfate. The resulting solution was concentrated and the residue purified via silica gel chromatography (6:1 hexane/EtOAc) to yield 447 mg of (*R*,*E*)-**56** as a clear oil (39%, 97:3 *E*/*Z*). NMR spectral data agreed with that previously reported in the literature.[20] Enantiopurity was

determined by conversion to (*R*,*E*)-2-benzoyl-4,8-dimethyl-nona-3,7-diene nitrile and analysis by chiral HPLC. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 5.16 (1H, d, *J* = 8.3 Hz), 5.02 (2H, tt, *J* = 6.9, 1.4 Hz), 4.61 (1H, d, *J* = 8.0 Hz), 1.92 (2H, q, *J* = 7.2 Hz), 1.77 (2H, t, *J* = 8.0 Hz), 1.64 (3H, s), 1.48 (3H, s), 1.29 (3H, s). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 144.4, 132.42, 124.08, 120.49, 120.14, 58.40, 39.57, 26.60, 26.11, 18.03, 16.84. $[\alpha]_D$ = -52.2 (20 °C, $CHCl_3$, c =1.15) (lit. (*R*,*E*)-**56** $[\alpha]_D$ = -52 (20 °C, $CHCl_3$, c =1))[20].

(*R*,*E*)-2-Benzoyl-4,8-dimethyl-nona-3,7-diene nitrile. To a solution of 100 mg (0.56 mmol) of (*R*,*E*)-**56** and 67 μL (0.56 mmol) of benzoyl chloride in 1 mL THF at 0 ^{o}C in a 2-necked, 25 mL round bottomed flask under argon was added 1 mL pyridine. The solution was allowed to warm to room temperature and stir for 4 h. A fine white precipitate formed. The solution was then diluted with 20 mL diethyl ether, washed with 20 mL of a 1 M aqueous solution of NH_4Cl, 20 mL of brine and the combine organic layers were dried over Na_2SO_4. The solution was filtered, concentrated and the residue purified by silica gel column chromatography (95:5 hexane/Et_2O) to yield 139 mg (88%) of (*R*,*E*)-2-benzoyl-4,8-dimethyl-nona-3,7-diene nitrile as a clear, colorless oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 8.05 (2H, m), 7.59 (1H, m), 7.47 (2H, m), 6.25 (1H, d, *J* = 9.1 Hz), 5.48 (1H, dd, *J* = 9.1, 1.1 Hz), 5.06 (1H, m), 2.12 (4H, m), 1.86 (3H, s), 1.67 (3H, s), 1.60 (3H, s). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ164.63, 147.66, 133.86, 132.56, 129.96, 128.58, 128.43, 122.85, 116.64, 115.40, 58.46, 39.26, 25.87, 25.62, 17.89, 17.21. HRMS (EI) calcd. for $C_{18}H_{21}NO_2$: 283.1567, found: 283.1572. Enantiomeric excess determined to be 98.5% by chiral HPLC (OJ column, 1% *i*-PrOH in hexanes, 1 mL/min). $[\alpha]_D$ = 20.3 (23 °C, EtOH, c = 1.01).

(*E*,*R*)-4-hydroxy-4,8-dimethyl-nona-2,7-diene nitrile ((*R*,*E*)-**57**). Followed procedure given for **21**, with 100 mg of (*R*,*E*)-**56** (0.56 mmol), 7 mg of **1** (0.014 mmol), 3 mL toluene, a reaction temperature of 23 ^{o}C, and a reaction time of 10 min. Purified via silica gel chromatography (6:4 hexane/Et_2O) to obtain 95 mg of (*R*,*E*)-**57** as a clear oil (95%). ^{1}H NMR (300 MHz, C_6D_6, ppm): δ 5.97 (1H, d, *J* = 16.0 Hz), 5.17 (1H, d, *J* = 16.0 Hz), 4.99 (1H, m), 1.71 (2H, m), 1.46 (3H, s), 1.12 (2H, m), 0.83 (1H, s), 0.72 (3H, s). ^{13}C NMR (75.4 MHz, C_6D_6, ppm): δ 160.45, 132.56, 124.56, 118.04, 98.09, 73.35, 41.82, 27.80, 26.11, 23.04, 18.04. HRMS (EI) calcd. for $C_{11}H_{17}NO$: 179.1307, found: 179.1310. IR (thin film): 3468, 2970, 2927, 2225, 1632, 1451, 1376, 1251, 1195, 1124. Enantiomeric excess determined to be 91.8 % by chiral HPLC (OB column, 5% *i*-PrOH in hexanes, 1 mL/min, 220 nm). $[\alpha]_D$ = 3.9 (20 °C, EtOH, c = 1.1).

(*R*,*E*)-1-Phenyl-non-1-en-3-ol ((*R*,*E*)-**15**). To a solution of 2.5 mg (0.0051 mmol) of dirhenium heptaoxide in 1 mL of Et_2O in a 25 mL 2-necked, round bottomed flask under argon at 23 ^{o}C was added 78 μL (0.41 mmol) of TMSNH*t*-Bu. The resulting yellow solution was stirred for 10 min prior to addition of 90 mg (0.41 mmol) of (*R*,*E*)-**14** as a solution in 1 mL of Et_2O. The resulting solution was then stirred for 30 min at 23 ^{o}C prior to concentration in vacuo. To the residue was added 135 mg K_2CO_3 and 2 mL MeOH and the suspension was stirred vigorously for 1 h. Addition of 20 mL of an aqueous saturated ammonium chloride solution, extraction with CH_2Cl_2 (2 x 50 mL), drying of the combine layers over Na_2SO_4, filtration and concentration. Purification by column chromatography (8:2 hexane/Et_2O) yielded 77 mg (86%) of (*R*,*E*)-**15** as a white, crystalline solid. Spectral

data agreed with that previously reported in the literature.[2] ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.35 (5H, m), 6.60 (1H, d, *J* = 15.9 Hz), 6.25 (1H, dd, *J* = 15.9, 6.9 Hz), 4.30 (1H, dt, *J* = 6.3, 6.3 Hz), 1.65 (3H, m), 1.4 (8H, m), 0.91 (3H, t, *J* = 6.8 Hz). ^{13}C NMR (300 MHz, $CDCl_3$, ppm): δ 137.0, 132.8, 130.4, 128.8, 127.8, 126.7, 73.3, 37.6, 32.0, 29.5, 25.6, 22.8, 14.3. Enantiomeric excess determined to be 82.6% by chiral HPLC (OJ column, 3% *i*-PrOH in hexanes, 1 mL/min).

(*E*)-*N*-*tert*-butyl-1-(4-methoxyphenyl) hept-2-enyl amine (**60**): To a solution of 6.5 mg (0.0125 mmol) of tetra-*n*-butyl ammonium perrhennate in 2 mL of DCM in a 25 mL 2-necked, round bottomed flask under argon at 23 ^{o}C was added 114 μL (0.6 mmol) of TMSNH*t*-Bu. The resulting yellow solution was stirred for 10 min prior to addition of 110 mg (0.5 mmol) of (*E*)-1-(4-methoxyphenyl)hept-2-en-1-ol. The resulting purple solution was then stirred for 90 min at 23 ^{o}C prior to concentration in vacuo, dilution with 20 mL Et_2O, washing with 50 mL a saturated aqueous solution of sodium bicarbonate, drying of the combine layers of K_2CO_3, filtration and concentration. Purification by column chromatography (95:5 CH_2Cl_2/MeOH) yielded 69 mg (51%) of **60** as a clear oil. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.27 (2H, m), 6.84 (2H, m), 5.58 (1H, dd, *J* = 15.4, 6.8 Hz), 5.48 (1H, dt, *J* = 15.4, 6.1 Hz), 4.32 (1H, d, *J* = 6.8 Hz), 3.78 (3H, s), 1.97 (2H, q, *J* = 6.6 Hz), 1.28 (4H, m), 1.07 (9H, s), 0.87 (3H, t, *J* = 7.2 Hz). ^{13}C NMR (75.4 MHz, $CDCl_3$, ppm): δ 158.17, 150.81, 138.58, 135.59, 129.80, 128.12, 113.60, 59.14, 55.17, 51.46, 31.92, 31.35, 30.22, 22.24, 13.90. HRMS (EI) calcd. for $C_{18}H_{29}NO$: 275.2249, found: 275.2254.

(1) The solvent columns are composed of activated alumina (A-2) and supported copper redox catalyst (Q-5 reactant). See: Pangborn, A.B.; Giardello, M.A.; Grubbs, R.H.; Rosen, R.K.; Timmers, F.J. *Organometallics* **1996**, *15*, 1518-1520.
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(15) Silver nitrate impregnated silica gel was prepared by added a solution of 4.3 g silver nitrate in 20 mL acetonitrile to 70 g of silica gel in a 1000 mL round bottomed flask. The mixture was placed on the rotovap to remove the majority of the solvent and then dried under high vacuum in the dark. The silica gel could be stored in the dark for prolonged periods of time.
(16) The isomeric compound (*E*)-**54** was prepared by addition of (*E*)-1-iodo-2-methyloct-1-ene to 3,5-bis-(trifluoromethyl)-benzaldehyde following the procedure outlined for compound (*R*,*E*)-**50**. ^{1}H NMR (300 MHz, $CDCl_3$, ppm): δ 7.84 (2H, s), 7.78 (1H, s), 5.60 (1H, d, *J* = 9.0 Hz), 5.33 (1H, dq, *J* = 8.9, 1.3 Hz), 2.07 (2H, t, *J* = 7.5 Hz), 1.85 (3H, d, *J* = 1.2 Hz), 1.36 (8H, m), 0.88 (3H, t, *J* = 6.8 Hz). ^{1}H NMR (300 MHz, C_6D_6, ppm): δ 8.21 (1H, s), 7.74 (1H, s), 6.33 (2H, m), 2.15 (2H, d, *J* = 1.2 Hz), 1.86 (3H, t, *J* = 7.4 Hz), 1.2 (8H, m), 0.91 (3H, t, *J*= 6.9 Hz). ^{1}H NMR NOE (300 MHz, C_6D_6, ppm): irradiation at 6.33 ppm (1H, m) enhanced signals at 8.21 ppm (2H, s) and 1.86 ppm (2H, t, *J* = 7.4 Hz). ^{13}C NMR (75 MHz, $CDCl_3$, ppm): δ 146.9, 142.0, 131.8 (q, *J* = 132 Hz), 123.7 (q, *J* = 1085 Hz), 126.3 (m), 126.2, 121.2 (m), 69.7, 39.7, 31.9, 29.1, 27.7, 22.8, 16.9, 14.2.
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